Event generation of large-angle Bhabha scattering at LEP2 energies

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Abstract

LABSMC Monte Carlo event generator is used to simulate Bhabha scattering at high energies. Different sources of radiative corrections are considered. The resulting precision is discussed.

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1 Introduction

In this note we are going to discuss the application the Monte Carlo event generator `LABSMC` [1] to the case of LEP2 energies. The topic is actual now in view of the analysis of LEP2 data. The experiment requires high precision theoretical predictions to perform more deep tests of the Standard Model and to look for a new physics.

Initially the `LABSMC` event generator was developed to simulate large–angle Bhabha scattering at energies of about a few GeV's at electron positron colliders like VEPP–2M and DAΦNE. The code included the Born level matrix element, the complete set of $\mathcal{O}(\alpha)$ QED RC, and the higher order leading logarithmic RC by means of the electron structure functions. The relevant set of formulae can be found in Ref. [2]. The generation of events is performed using an original algorithm, which combines advantages of semi–analytical programs and Monte Carlo generators.

The structure of our event generator was described recently in paper [1]. The extension for higher energies is done by introducing electroweak (EW) contributions, such as Z-exchange, into the matrix elements. The third [3] and fourth [4] order leading logarithmic photonic corrections were also included in the new version. So, the structure of the code is kept the same, and we have to describe now what kind of EW effects were included in our code to work with large–angle Bhabha at LEP2. In particular we are going to consider the region of radiative return to the Z-peak in radiative Bhabha scattering. To estimate the resulting theoretical uncertainty, one has to analyse various sources of radiative corrections (RC).

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2 Electroweak contributions

The set of electroweak effects was included according to Refs. [5, 6, 7]. The Born level cross section in the program contains now both the photon and Z-boson exchange contributions (it is used also as a kernel cross section for higher order leading log radiative corrections). The first order virtual and soft EW RC were taken directly from the semi–analytical code `ALIBABA` [6]. The EW matrix element for radiative Bhabha is taken from Ref. [7]. A comparison of the Bhabha cross–section integrated over photons is in a reasonably good agreement (see Table 1, error–bars are dropped) with the published numbers of other codes [8].

Table 1: Comparison with Fig. 21 from Ref. [8], cross-sections in pb.

E_{CM}, GeV	`BHWIDE`	`TOPAZ0`	`BHAGENE3`	`UNIBAB`	`SABSPV`	`BHAGEN95`	`LABSMC`
	$\vartheta_{\rm acol} = 10°$						
175	35.257	35.455	34.690	34.498	35.740	35.847	35.337
190	29.899	30.024	28.780	29.189	30.270	30.352	29.941
205	25.593	25.738	24.690	25.976	25.960	26.007	25.687
	$\vartheta_{\rm acol} = 25°$						
175	39.741	40.487	39.170	39.521	40.240	40.505	40.029
190	33.698	34.336	32.400	33.512	34.100	34.331	33.954
205	28.929	29.460	27.840	28.710	29.280	29.437	29.178

3 Radiative return with a visible photon

At LEP2 the radiative return to the Z-peak due to photon or pair radiation gives a sizable contribution to the cross–section. This process is used itself in particular to look for anomalous gauge boson couplings.

The pure tree level matrix element [7] for radiative process

$$e^+ \ + \ e^- \ \longrightarrow \ e^+ \ + \ e^- \ + \ \gamma \ + \ (n\gamma) \tag{1}$$

was supplemented by radiative corrections due to initial state soft and hard collinear radiation by means of the electron structure function approach [9]. The electron–positron pair production was taken into account in the same way. As an energy scale for the structure functions we took the t-channel momentum transferred, because the corresponding diagrams are dominant. The vacuum polarization correction to the photon propagators is applied as well.

In Table 2 we put the result for the following conditions: E_{CM}=183, 189 GeV; $|\cos\theta_{e^\pm}| < 0.95$; at least one electron has $|\cos\theta_e| < 0.7$; electrons should have transverse momenta above 1 GeV; the final particles are to be isolated by at least 20 degree from each other; the total observed energy $> 0.8\ E_{CM}$; $|\cos\theta_\gamma| < 0.7$. In the columns *without Z-peak* we excluded the events with the invariant mass of the electron positron pair in the range 85 GeV $< M_{ee} <$ 95 GeV. As could be seen from the numbers, the ISR LLA corrections are in this case of the order 2%. The additional non–standard LLA corrections, which were found in Ref. [10], make a small shift of the correction; but an independent verification of the investigation is required.

The complete set of $\mathcal{O}(\alpha)$ EW radiative corrections to the process (1) is unknown. To estimate the uncertainty of our result we look at the relative size of the known leading and sub–leading $\mathcal{O}(\alpha)$ RC to the Bhabha process itself. For an analogous set of cuts for Bhabha scattering for the difference of the correction values we have $\delta_{\mathrm{tot}} - \delta_{\mathrm{LLA}} \approx 1\%$[1]. In this way we estimate the precision of our results for the radiative process (1) to be of the order 1.5%.

Table 2: The cross section in pb of radiative Bhabha with a visible photon in different approximations.

	total		without Z-peak	
E_{CM} [GeV]	183	189	183	189
tree–level	0.9817	0.9146	0.8251	0.7727
vacuum polarisation	1.1022	1.0342	0.9630	0.8853
vac. pol. + ISR LLA	1.0842	1.0088	0.9346	0.8770

4 Conclusions

The precision of the theoretical predictions, which can be obtained by means of the presented code for inclusive large–angle Bhabha scattering at LEP2, is estimated to be of the order 0.2%. It is defined mainly by the unknown radiative corrections of the order $\mathcal{O}((\alpha/\pi)^2L) \approx 10^{-4}$. The coefficients before these terms are not too large, as was seen in the case of small–angle Bhabha scattering. At LEP2 energies in the large–angle Bhabha process the t-channel photon exchange is dominant. Nevertheless, a correct treatment of the electroweak Born and the first order corrections is important. The technical precision of the code is to be verified in further test and comparisons with other codes. By means of the comparisons of the semi–analytical branch and the pure Monte Carlo one of the code we have a good control of such parameters as the precision of numerical integration and the number of events to be generated. That allows to reach an ordered level of the uncertainty in numerical evaluations.

Another source of uncertainties is an incomplete treatment of pair production. In the current version of the code the pair production corrections are evaluated in the $\mathcal{O}(\alpha^2L^2)$ structure function approach. Both the singlet and non–singlet electron pairs are included. A special brunch of the code to scrutinise the pair production [11] is in progress.

The inclusion of the third and fourth order LLA photonic corrections allows not to use exponentiation. A simple estimate shows that the difference between the two treatments at LEP2 is negligible, while the exponentiation requires a quite different event generation procedure.

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[1]The special cut on the scattering angle of "at least one electron has $|\cos\theta_e| < 0.7$" is similar to the narrow–wide event selection in small–angle Bhabha at LEP1. In both cases we see a considerable reduction of the RC size. If we apply this cut, the difference $\delta_{\mathrm{tot}} - \delta_{\mathrm{LLA}}$ is well below the 1% level.

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